Task Force on Corrosion Control

Terms of Reference

- **Assess current on-going corrosion control efforts with particular attention to:**
  - **Duplication of research efforts**
  - **Application of current and future technology which currently exists in one area to other areas**
  - **Current state of operator and maintenance personnel training**
  - **Current state of maintenance processes**
  - **Incorporation of corrosion control and maintainability in current acquisition programs**
  - **Identify unique environments important to National Security but with little commercial application**
- **Determine which areas would provide the most significant advances in combat readiness if adequate resources were applied**
- **Assess best commercial practices and their applicability**

Participants

Mr. Larry Lynn, Co-Chairman
RADM(R) Steve Heilman, LMI, Co-Chairman
Col. Sarah Smith, Executive Secretary
LtC Dave Robertson, DSB Representative

Dr. Robert Baboian, Consultant

Mr. Aubrey Carter, Delta Air Lines

Dr. Mike Cieslak, Sandia National Labs

Dr. Dave Diehl, PPG Industries

Dr. Joe Farmer, Lawrence Livermore NL

Prof. Bob Green, Johns Hopkins U

Prof. Arthur Heuer, Case Western Res U

Mr. Brian Manty, MB-TSI

Capt(R) William Needham, NSWC

Dr. Dick Pinckert, Boeing

Dr. Rick Ricker, NIST

Prof. John Scully, Univ. Of Virginia

Prof. Bruce Thompson, Iowa State U

Dr. Neil Thompson, CC Technologies, NACE

Government Advisors

Mr. Roger Griswold, USAF

Maj. Claxton Johnson, USMC

Capt. Phil Johnson, USN

CW5 Theodore Walker, USA

What is "Corrosion"?

"The deterioration of a material or its properties due to a reaction of that material with its chemical [and physical] environment"*

- Aircraft
- Ships
- Ground vehicles
- Weapon systems
- Electronics
- Munitions
- Infrastructure
- Nuclear

Each has different corrosion problems and approaches to prevention, mitigation and remediation

- Research
- Design
- Manufacture
- Testing
- Deployment
- Maintenance
- Refurbishment
- Disposal

- **Large fraction of maintenance and replacement costs are due to corrosion, wear and fatigue which are strongly interactive**

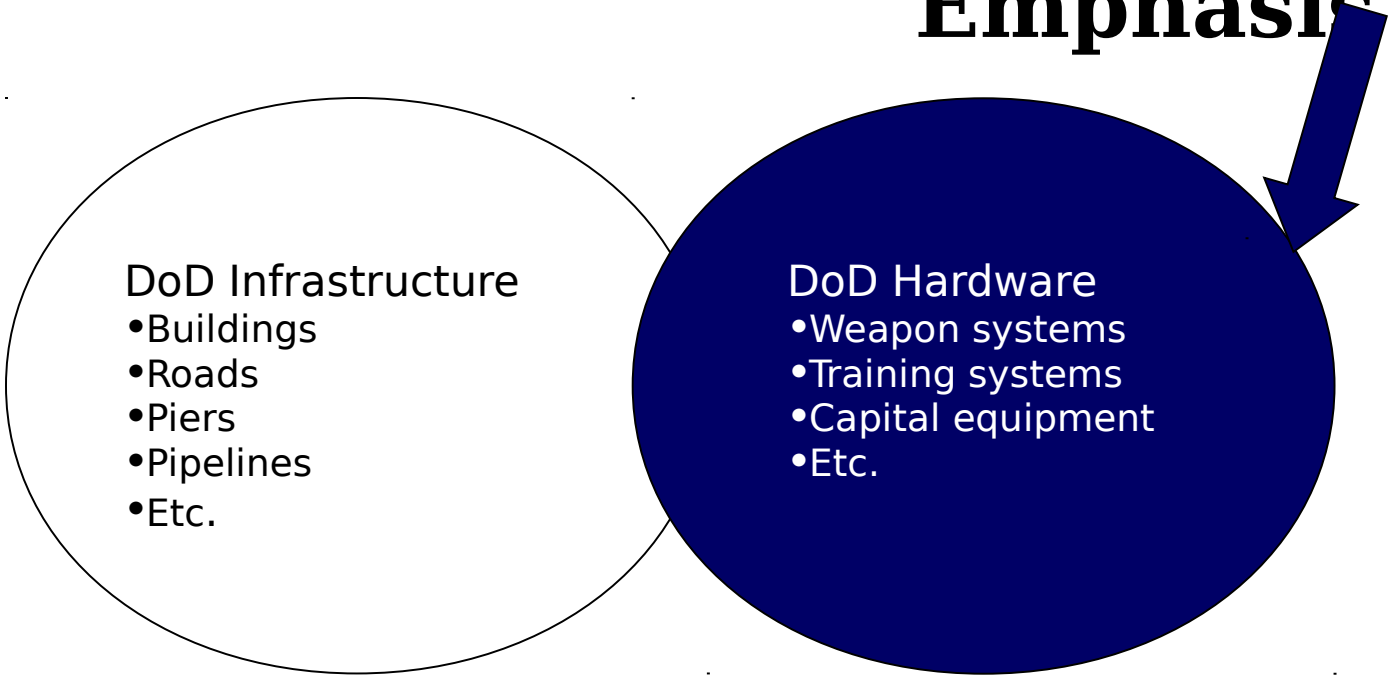
*DoD Report to Congress, Dec 2003

Does Corrosion Matter?

- **All materials corrode**
- **Corroded material is bad**
  - **Reduces structural integrity**
  - **Increases life-cycle cost**
  - **Decreases Operational Availability (Ao)**
  - **Kills people**
- **Negative effects of corrosion highly correlated to amount of corrosion**
  - **Untreated corrosion always gets worse**
  - **A lot of corrosion results in failure**

USMC Truck
Ranked CC-4: "Item requires repair at the intermediate level before painting"

Task Force Emphasis

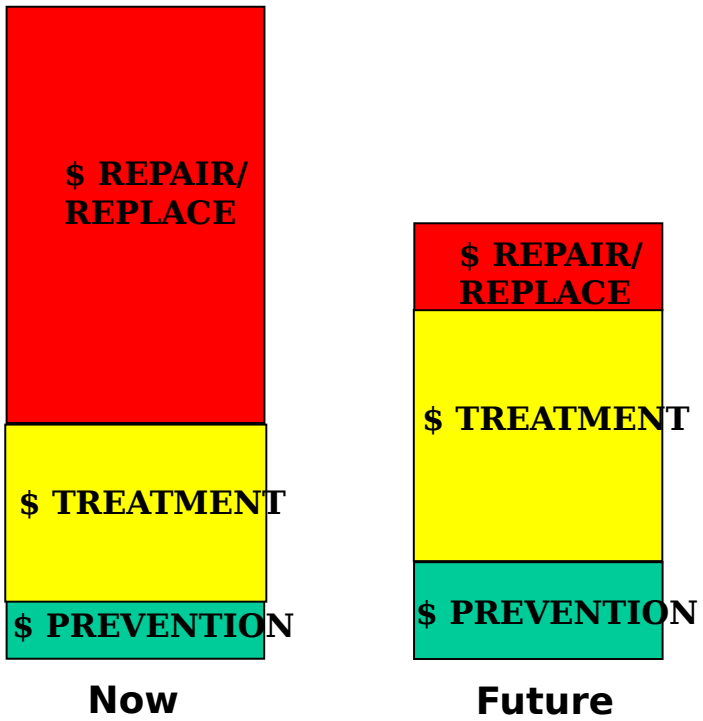


- **GAO estimates DoD corrosion costs at $10B - $20B/year**
- **Current impacts and costs of corrosion are highly suspect and probably understated**
- **Corrosion is likely to be a bigger problem in the future than present**

Why Address Corrosion?

Cost

Estimate 30% of current DoD corrosion cost could be avoided through investment in sustainment, design, and manufacture



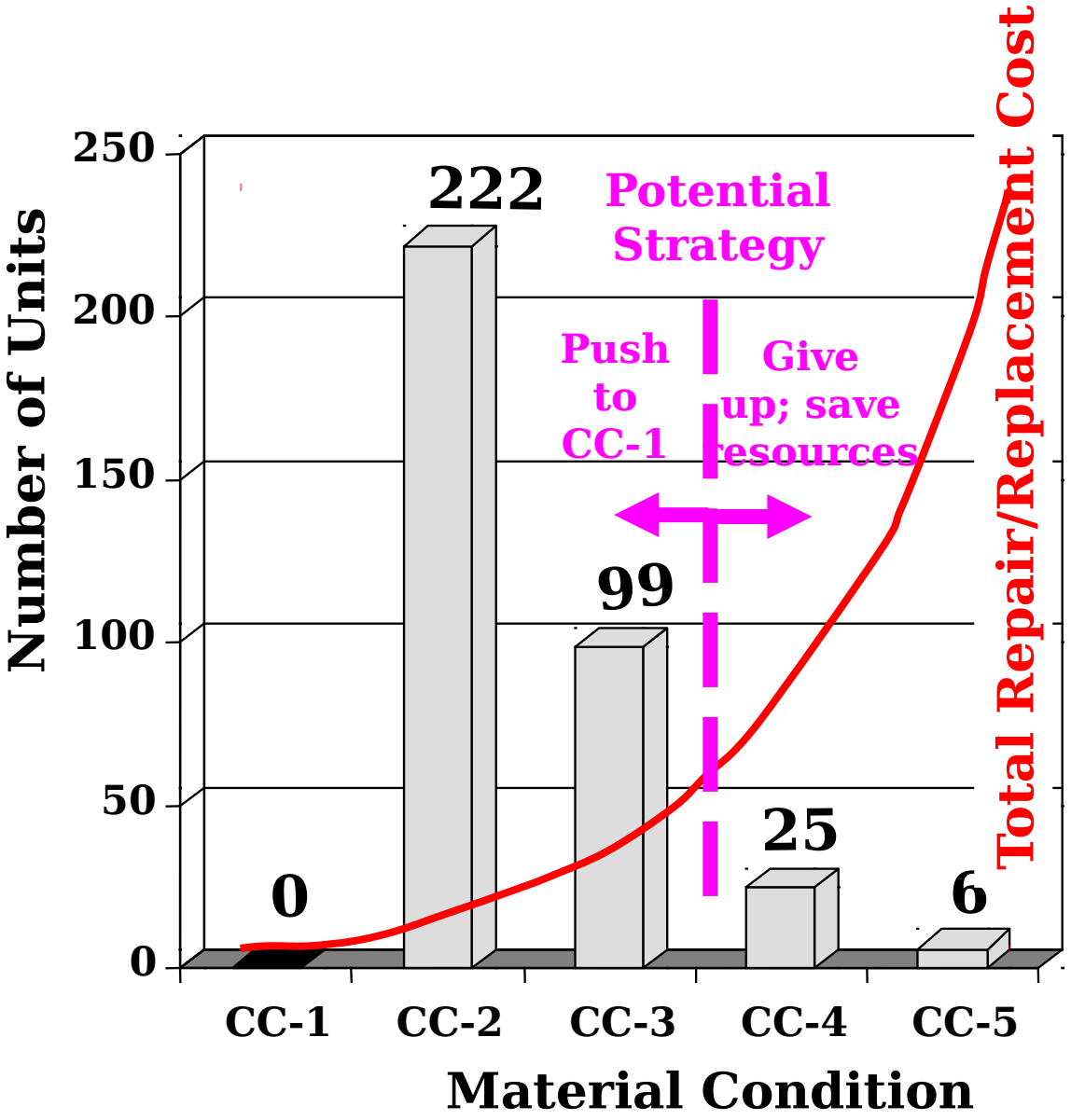
Readiness

(Ao) clearly improves with reduction of corrosion

Safety

e.g. 9 fatalities in 10 years in Army Aviation were specifically related to corrosion

Strategy Option



Action Required
CC-1: No Repair
CC2: Operator Maintenance
CC-3: Surface repair & paint at Intermediate level
CC-4: Structural repair & paint at Intermediate level
CC-5: Must Replace Item

USMC definitions

USMC Data: Inspection team review of 352 vehicles of 11th MEU

Outline: Barriers

Leadership Commitment & Policy

- **Leadership corrosion awareness**
- **Policy change**
- **Basis for decisions & policy**

Design & Manufacturing Practices

Maintenance Practices

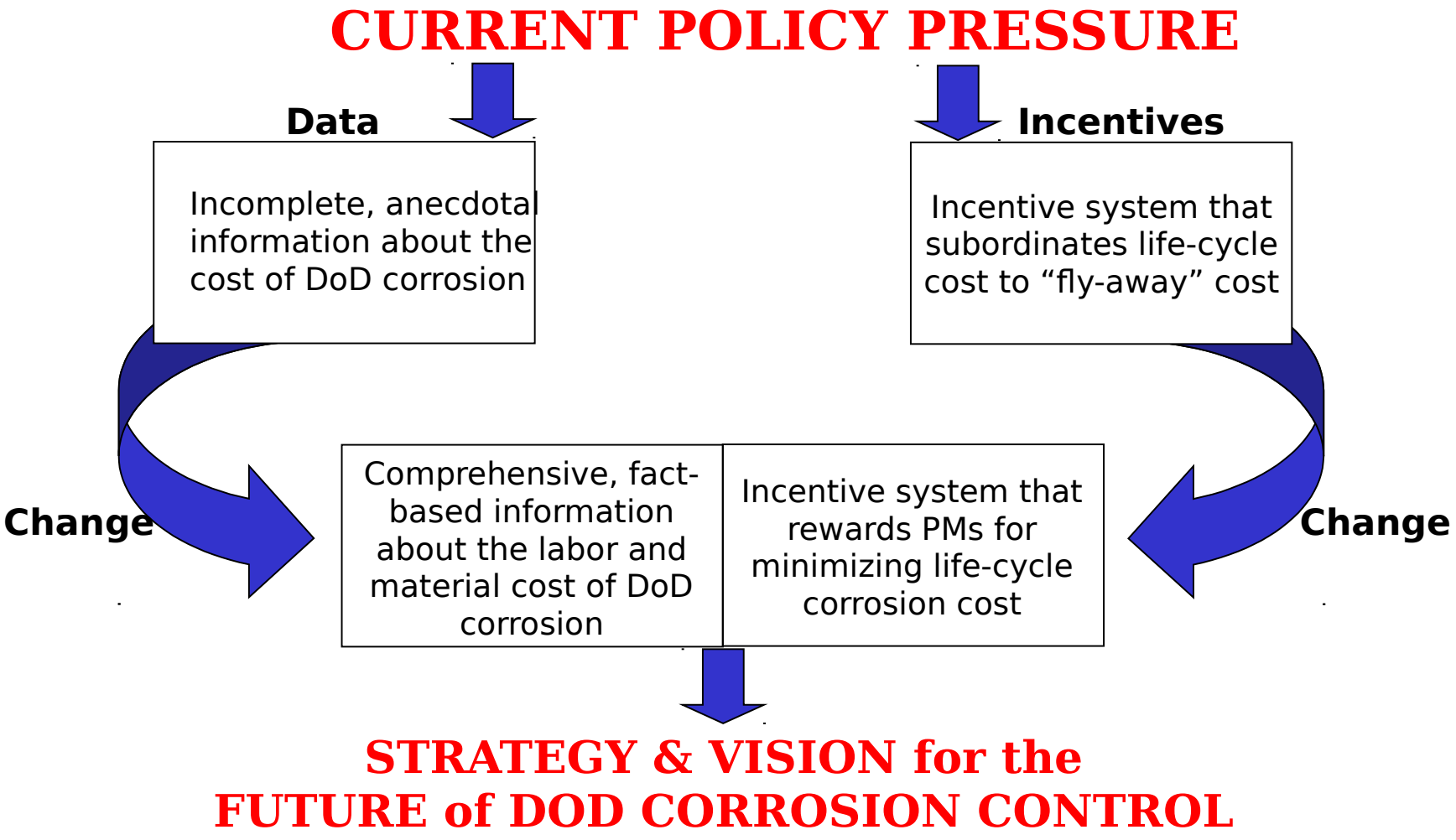
Funding & Management

Scientific Basis for Prevention/Mitigation of Corrosion

Leadership Awareness

- **Limited understanding of corrosion cost and impacts among decision makers**
  - **Anecdotal reports, observations; lack of accurate & meaningful data**
- **New systems continue to be built with a disparity between Program Managers who control corrosion prevention decisions and O&S Users who incur the actual corrosion costs**
  - **Leads to mentality of “build it cheap (budget) and fix it later”**
  - **Warfighters should have very strong voice in the design and procurement stages**
- **Problem is not the Program Manager, it is the system that incentivizes minimum acquisition cost rather than Life Cycle Cost (LCC)**

Policy Must Change



Basis of Decisions

- **O&S metrics and data must become objective & fact-based**
  - **Currently subjective and anecdotal**
- **Leadership must define and quantify the distinction between acceptable and unacceptable corrosion cost**
  - **Performance standards are currently ambiguous**
  - **Substandard performance is not defined**
  - **Incentives can only be effective if objective is clear**
- **For the foreseeable future, prediction of corrosion effects must rely on an integration of**
  - **Judgment of independent experts**
  - **Accelerated testing of prototypes and early products**
  - **Detailed modeling of limited numbers of suspect areas**

Must have Life Cycle management mindset and d

Leadership Commitment and Policy - Findings

- **Corrosion prevention has not been a priority across DoD**
- **DoD does not have accurate direct and indirect costs of corrosion prevention, mitigation & remediation, nor does it know what the costs should be**
- **Since corrosion costs are unclear, Service decision-makers lack compelling arguments for resources to reduce Life Cycle Costs**
- **At the platform level, decision-makers also lack effective corrosion standards and test methods to assess corrosion performance**
- **Few decision-makers in a position to reduce life-cycle corrosion costs are incentivized to do so**

Outline: Design & Manufacturing

Leadership Commitment & Policy

Design & Manufacturing Practices

- **Incentives**
- **Metrics & Standards**
- **Testing**
- **Advanced technology**

Maintenance Practices

Funding & Management

Scientific Basis for Prevention/Mitigation of Corrosion

Design & Mfg. Anecdotal Case

FMTV vehicle prototype tested at Aberdeen

- **In specification, corrosion engineers recommended to limit acceptable results in accelerated testing, to stage 1 corrosion**
- **In tradeoff with other factors, contract allowed up to stage 3 corrosion**
- **This allowed contractor to use non-galvanized steel (galvanized would have cost ~$200/unit more)**
- **Tests showed substantial stage 3 which was unacceptable to users**
- **Result was very large expenditures to redesign and correct problems**

Corrosion Test Plan, Prepared for U.S. Army
Tank-Automotive and Armaments command,
Warren, MI, Contract Number DAAE07-92-C-R001

- not exhibit corrosion greater than the commercial design requirements
  - The vehicle shall not exhibit corrosion greater than Stage 3
- Corrosion rating system for the FMTV
  - Stage 1: Corrosion deposit on the surface accompanied by minor etching and pitting. Base metal is sound.
  - Stage 2: Corrosion resulting in erosion of material from the surface. Base metal is sound.
  - Stage 3: Similar to Stage 2, except that the base metal in the corroded areas is unsound and small pinholes may be present.
  - Stage 4: Corrosion advanced where the surface has been penetrated. No base metal remains at the point of the most severe corrosion. There are rust holes in the surface area or base metal is completely missing along the edge.

The current system provides the wrong incentive

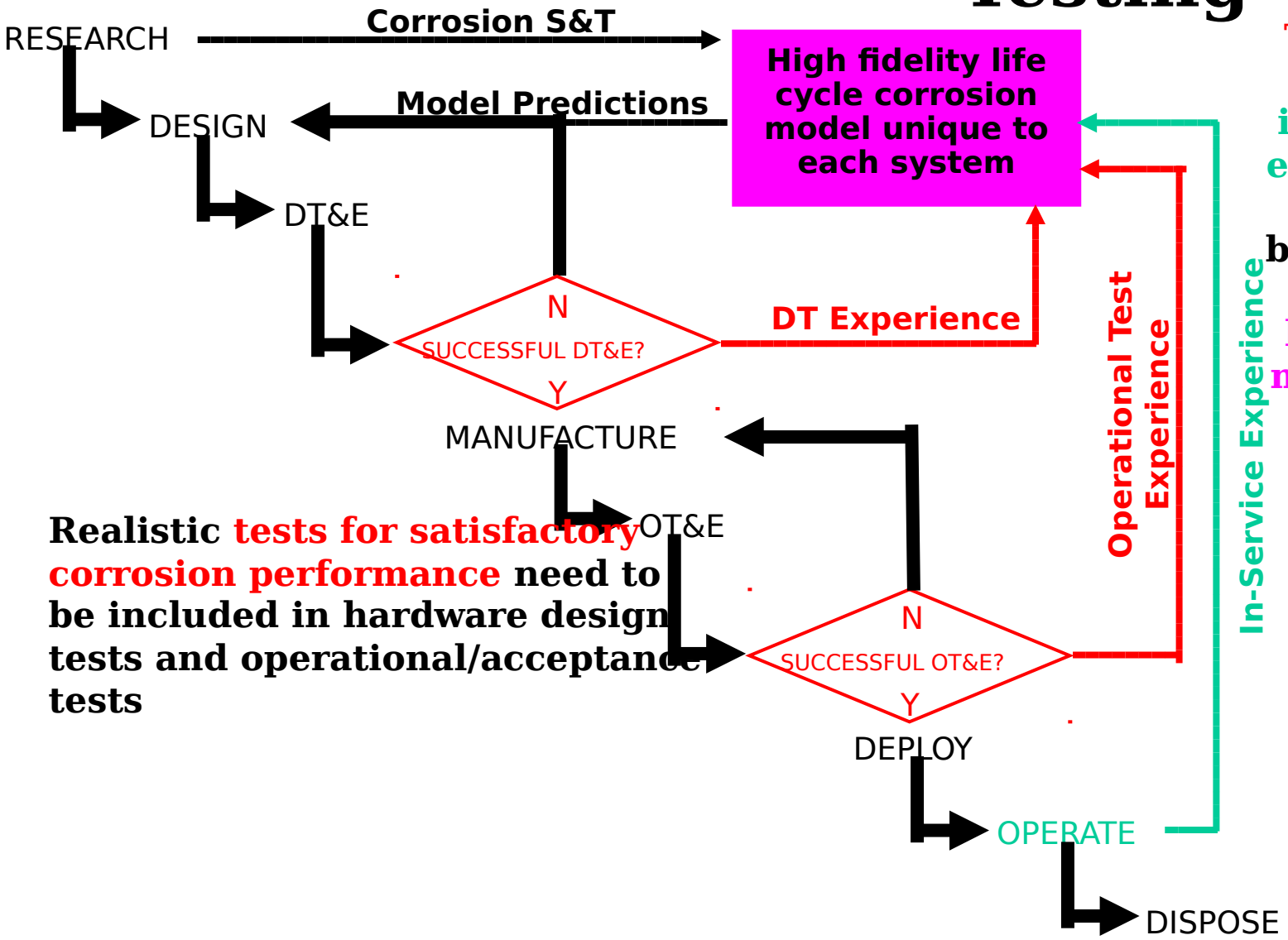
Design & Mfg. Incentives

- **Incentives for corrosion prevention during the design, manufacture, and acquisition process must be based on reduction of the LCC**
- **OT&E Community & Warfighter supported by independent expert panel should have major responsibility for judging success**
- **Metrics and data reporting systems must be objective and accurate**
- **Systemic Problems**
  - **Corrosion issues generally require spending funds now for payoff 5-20 years later**
  - **Program managers of today are usually gone in a few years**
  - **Costs and savings can only be estimated but must be estimated consistently by experts**
- **Nature of incentives**
  - **Services: Retain O&S cost savings for programs within that Service**
  - **PMs: More flexibility or funds for other aspects of program**
  - **Industry: Positive and negative profit incentives**

Design & Mfg. Metrics & Standards

- **Implementation of incentives requires metrics and standards**
- **A standard method for probabilistic predictions of mission readiness, personnel safety and LCC from accelerated corrosion test data must be established, documented, and uniformly applied**
  - **Accelerated testing must be based on documented, effective standards**
  - **DoD must participate in organizations involved in standards preparation**
- **A rigorous mathematical formulation of ROI for corrosion prevention must be documented and consistently used**
- **Testing is essential at every stage**
  - **Provide credible data**
  - **Validate and improve estimates and models**

Corrosion Modeling & Testing



Test data and in-service experience needs to be iterated back to life-cycle model and design process.

Realistic tests for satisfactory corrosion performance need to be included in hardware design tests and operational/acceptance tests

Design & Mfg. Advanced Technology

- **Focus on:**
  - **High performance materials**
  - **Better joining technology**
  - **Improved diagnostics and prognostics**
  - **Green technology and risk assessment**

Design & Manufacturing Findings

- **The design phase largely establishes future corrosion & LCC**
  - **Material, coatings selection and structural aspects are critical**
  - **Corrosion specialists must participate**
  - **Consider most advanced technologies from commercial world**
- **Predictive corrosion models adequate for guiding the design of weapons systems do not exist**
- **Accounting systems adequate for estimating return on investment (ROI) do not exist**
- **Acquisition and design personnel are not empowered with the training necessary to minimize the impact of corrosion on life cycle costs**
- **Independent expert panels are not used to review the selection of corrosion resistant materials used in new systems**
- **Existing metrics and standards vary widely**

Recommendation #1

1. **Promulgate and enforce policy emphasizing LCC over acquisition costs in procurement and provide the incentives and training to assure that corrosion costs are fully considered in design, manufacturing, and maintenance.**
   - **Create independent team of corrosion experts to review all programs coming to the DAB and all maintenance plans to provide the expertise necessary to decision makers (<$1M)**
   - **Develop incentive structures to assure corrosion/LCC considerations in all designs and manufacturing**
     - **Motivate PMs with program flexibility**
     - **Motivate contractors with “carrot/stick” fee incentive contracts**
   - **Mandate corrosion testing & reporting at all stages of development (see Rec#2)**
   - **Issue directive to require that all major weapon system Corrosion Prevention Advisory Team (CPAT) members complete a Defense Acquisition University (DAU) developed course on corrosion control**
   - **Accelerate the introduction of activity based cost accounting to ensure future visibility into actual LCC and cost of corrosion**

Recommendation #2

2. **Mandate and implement comprehensive and accurate corrosion data reporting systems across DoD, using standard metrics and definitions**
   - **Contract for support in developing standard definitions, metrics, etc to be completed and promulgated within one year ($5M)**
   - **Direct Services to conform to these standards and to enable capture of complete and accurate O, I and D * level corrosion man-hour, material and cost data**
   - **Use these data to make fact-based decisions regarding corrosion and corrosion cost and to track progress of platform material condition improvement efforts (ROI). (Cost for analysis included in contract above)**

*** Organization, Intermediate, Depot**

Outline: Maintenance Practices

Leadership Commitment & Policy

Design & Manufacturing Practices

Maintenance Practices

- **Maintenance practices**
- **Assessment of state of corrosion**
- **Training**

Funding & Management

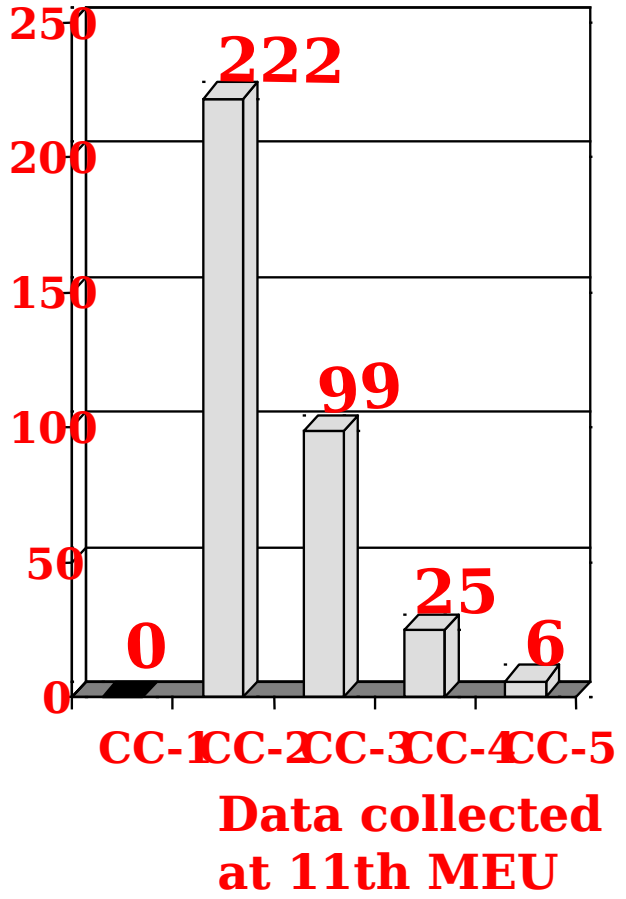
Scientific Basis for Prevention/Mitigation of Corrosion

Maintenance Practices

- **Cost of corrosion is primarily the current cost of maintaining or replacing existing assets**
- **Improved maintenance affords the only means of reducing the current cost of corrosion**
- **Benchmarking studies determine best practice maintenance in industry and within DOD**
  - **USMC model for inspection of ground vehicles and equipment**
  - **Delta's aircraft maintenance program adopted to DOD needs**
  - **DOT pipeline integrity regulations for pipelines**
- **Corrosion monitoring and inspection must be closely tied to maintenance practices**
- **Lessons learned from corrosion maintenance should drive design, acquisition, and specifications.**

Best Practices – Periodic Assessment

- **USMC model**
  - 5 man team assessed 352 equipment items of 11th MEU in 3.5 days and sensitized/trained unit personnel in process
- **Extrapolates to ~$25M for 600,000 items in DoD (estimate)**
  - ~30 of these 5-person teams could assess/ year
- **Conducting such an inspection with independent, corrosion-expert teams would provide:**
  - Quantitative understanding of the problem
  - Solid data base on which to build future efforts
  - Basis of a corrosion LCC strategy: repair/replace



Best Practices – Maintenance Training

- **Current Corrosion Training**
  - **Organization Level (Soldier, Sailor, Airman, Marine)**
    - **Knowledge of importance of corrosion**
    - **Primarily On the Job (OJT), and exposure to assessment teams of corrosion professionals**
  - **Intermediate Level (military and civilian)**
    - **Knowledge of short term corrosion prevention measures**
    - **Technical training for corrosion prevention**
  - **Depot Level (private and public)**
    - **Knowledge of long term corrosion measures**
    - **Inspector training for coating application and QA**
- **The emphasis on corrosion in DoD and the high cost of corrosion necessitates improved awareness training for operators and maintainers**

Maintenance - Findings

- **Extent of maintenance needs and current state of corrosion is not well characterized for most assets**
- **Quantitative understanding of the corrosion problem requires comprehensive, on-site assessments**
- **It has been shown in industry that major savings in corrosion cost can be achieved through instituting “best practice” engineering and maintenance strategies**
- **Appreciation and implementation of corrosion control practices varies significantly throughout the services**
  - **Corrosion control training and awareness among maintainers must be enhanced**

Recommendation #3

3. **Fund contract for comprehensive assessment of all DoD weapon system equipment with ~30 five-person teams of corrosion experts and use the results to develop and implement a corrosion strategy**
   - **Provide separate funding line to support annual assessment teams, to provide the means and expertise to manage ongoing maintenance efforts and to support organizational level training and maintenance ($25M)**
   - **Implement well defined maintenance programs that includes continuous corrosion performance improvement and continuing assessment and reporting**
   - **Require each Service to contract and execute its part**
   - **All results to be reported to common data base for analysis and to support the development of a joint strategy for corrosion maintenance that accommodates the unique factors associated with each Service (and system)**
   - **Extend assessment database to capture existing aircraft and ship corrosion data**
   - **Direct that Services establish best practices maintenance plans, benchmarking and providing adequate training to all involved personnel at operator, intermediate and depot levels**

Outline: Funding & Management

Leadership Commitment & Policy

Design & Manufacturing Practices

Maintenance Practices

Funding & Management

Scientific Basis for Prevention/Mitigation of Corrosion

Funding & Management Findings

- **Effective corrosion executive authority to advocate corrosion-related issues/funding is lacking at the Service level**
- **Corrosion S&T funding is small and fragmented**
  - **Funded out of unrelated R&D accounts within DoD (SBIR, SERDP, etc.)**
- **Dollars devoted to corrosion prevention during weapon system acquisition have historically proved insufficient**
- **O&M corrosion remediation budget does not exist**
- **Assuming an annual DoD weapon system/hardware corrosion cost of $10B/yr, a potential reduction of 15% (~$1.5B) by 2015 and an average ROI of 10:1, an annual investment of $58M/yr per Service is required**

Recommendation #4

4. **Establish Corrosion Executive for each Service with responsibility for oversight and reporting and full authority over corrosion-specific funding and a strong voice in corrosion-related funding**
   - **Fund new corrosion mitigation and control initiatives by requiring each Service to:**
     - **Establish PE in POM06 of $15M as a starting point**
     - **Submit and fund plan, concurrent with PR07, to invest and realize 10% savings (or $300M/yr) in corrosion costs by 2012, well into "self financing"**
     - **In absence of credible plan, include $100M in PR07 and each of the out years**
   - **Require each Service to provide $10M/yr beginning in FY06 to initiate remediation as indicated by results of the comprehensive assessment**

Outline: S&T

Leadership Commitment & Policy

Design & Manufacturing Practices

Maintenance Practices

Funding & Management

Scientific Basis for Prevention/Mitigation of Corrosion

Major S&T Objectives

- **Science-Based Understanding**
  - **Develop robust mechanistic basis of corrosion to enable reliable accelerated testing**
  - **Develop Improved materials science tool set**
- **Integrated/Predictive Tools for System Design and Management**
  - **Develop macroscopic Model for Evolution of Corrosion Damage**
  - **Develop sensor technology for early warning, data collection, and performance confirmation**
  - **Develop Mathematical tools to enable simulation and prediction**
- **Understanding of Evolving Materials and Environmental Issues**
  - **Develop the scientific basis needed for:**
    - **Acceptance and reliability of replacement materials**
    - **Green technologies needed for corrosion control for environmental compliance**
    - **Incorporation and use of emerging materials**
    - **Extension of legacy materials beyond original design life**

S&T Findings

- **Traditional approaches to improve corrosion control by S&T are not sufficient.** ***(i.e.,empirical testing, trial and error, field experience, etc.)***
- **Adequate predictive tools for life cycle analysis are not yet available.**
  - **Reliable probabilistic and deterministic assessment methods are not available to enable condition based maintenance plus, prognostics, and life prediction.**
  - **Macroscopic Models for Evolution of Corrosion Damage are lacking**
- **The aging of existing materials and more stringent environmental issues are increasing the difficultly of providing cost effective corrosion control**
- **The emerging/evolving new structural materials will have their own corrosion problems that are not yet known or understood**

S&T Findings

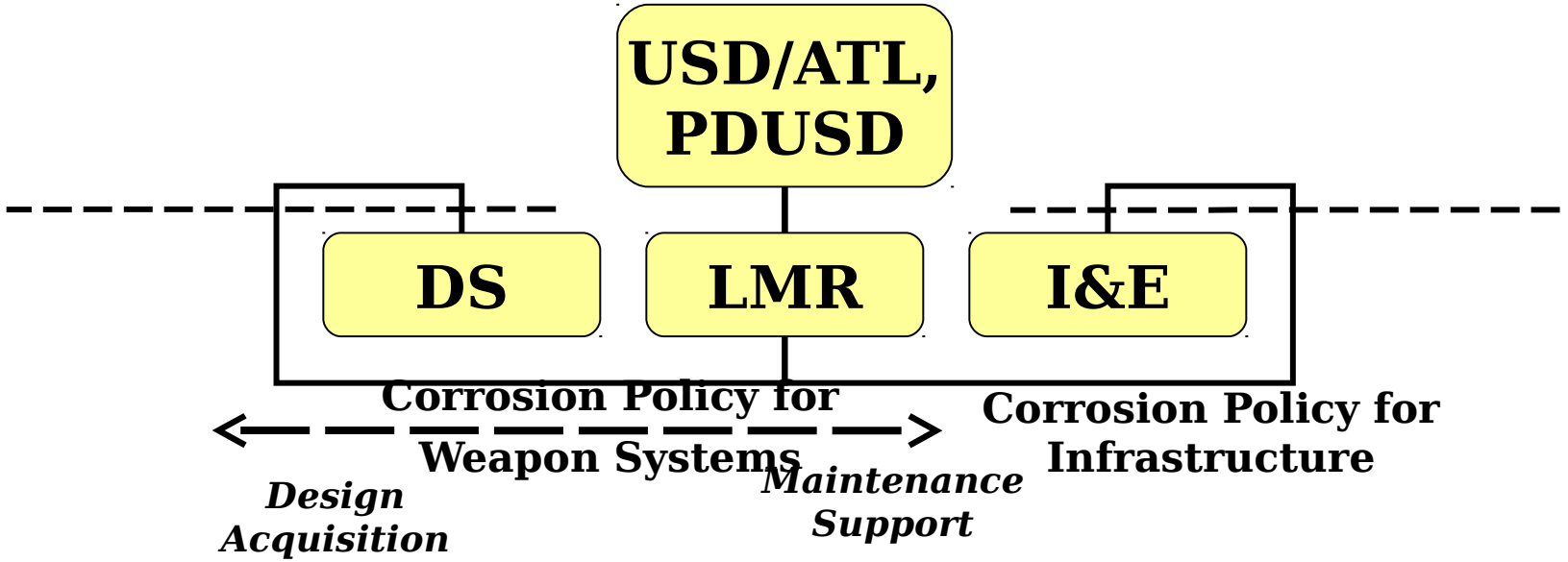
- **Duplication of research efforts**
  - **Duplication of effort is not a problem; the community is small and there is ample communication across the services in the corrosion area**
  - **DoD archive of papers include many with empirical knowledge so data base cannot be extrapolated to new situations, longer time periods, etc. outside of existing experience base**
- **Corrosion S&T funding is too small**
  - **Largely comprised of either environmentally driven efforts (EPA, OSHA) or Congressional adds**
  - **Current S&T portfolios are very technological but short on basic understanding of corrosion science**
- **Steady long term R&D funding for long-term problem yields higher probability of successful application**
  - **R&D portfolio should contain mix of long and short term topics**

Recommendation #5

5. **Refocus and reinvigorate corrosion S&T portfolio; triple the effective funding in this area (+$20M)**
   - **Particular emphasis on:**
     - **Development of a materials-corrosion toolset that emphasizes science-based modeling & simulation**
     - **Fundamental mechanistic understandings of corrosion phenomena as well as accelerated tasting**
     - **Substitutes for effective corrosion prevention materials which are being withdrawn due to environmental and safety considerations**
     - **Newly developed materials**
     - **Non-destructive corrosion sensing/measurement in the field as feedback to prognostic and condition-based maintenance tools**

Summary of Recommendations

1. **Promulgate and enforce policy emphasizing LCC over acquisition costs in procurement and provide the incentives and training to assure that corrosion costs are fully considered in design, manufacturing, and maintenance.**
2. **Mandate and implement comprehensive and accurate corrosion data reporting systems across DoD using standard metrics & definitions**
3. **Fund contract for comprehensive assessment of all DoD weapon system equipment with ~30 five-person teams of corrosion experts and use the results to develop and implement a corrosion strategy**
4. **Establish Corrosion Executive for each Service with responsibility for oversight and reporting and full authority over corrosion-specific funding and a strong voice in corrosion-related funding**
5. **Refocus and reinvigorate corrosion S&T portfolio; triple the effective funding in this area (+$20M)**



- **Separate, dedicated policy sponsorship for weapons systems and infrastructure desirable**
- **Alternatives for weapon systems corrosion leadership – choice of:**
  - **DS (DAB leadership) – not focused on O&S (maintenance)**
  - **LMR – limited influence in R&D (design)**

Additional Costs Estimated

Recommendation	OSD? (FY05)	Services (FY06)
#1	<$1M	
#2	$5M	
#3	$25M	
#4a. New		$45M
#4b. Continue Assessment	$25M	
#5	$20M	$20M